Minimizing NO2 Emissions from Catalyst-Based Diesel Particulate Filters

IDRAC Meeting

February 6, 2002

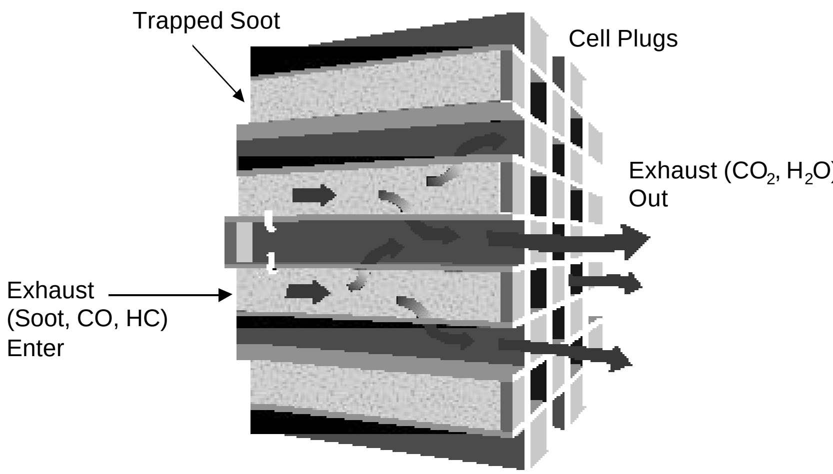
Manufacturers of Emission Controls Association

www.meca.org

Presentation Outline

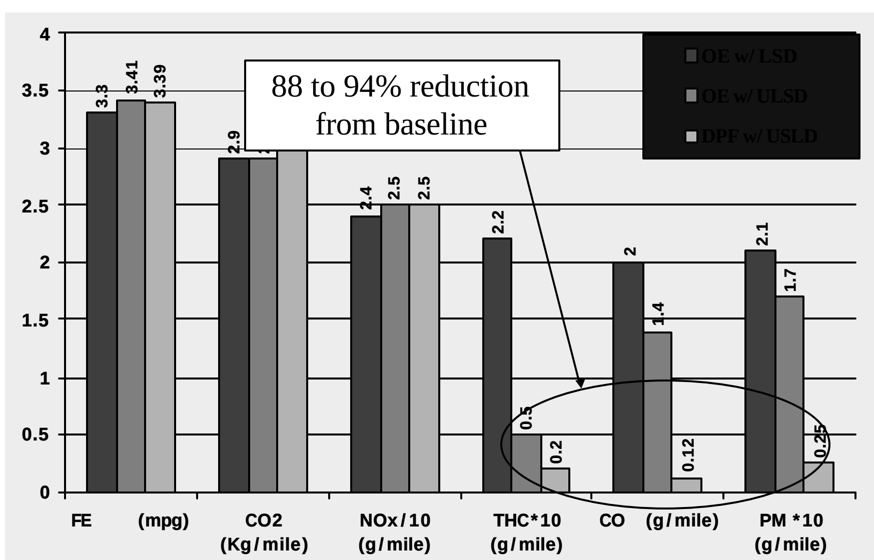
- Background
- Overview: Diesel Particulate Filter Emission Control Performance
- The Role of NO2 in Catalyst-Based Diesel Particulate Filters
- Minimizing NO2 Emissions
- Recommendations
- Conclusion

Diesel Particulate Filter

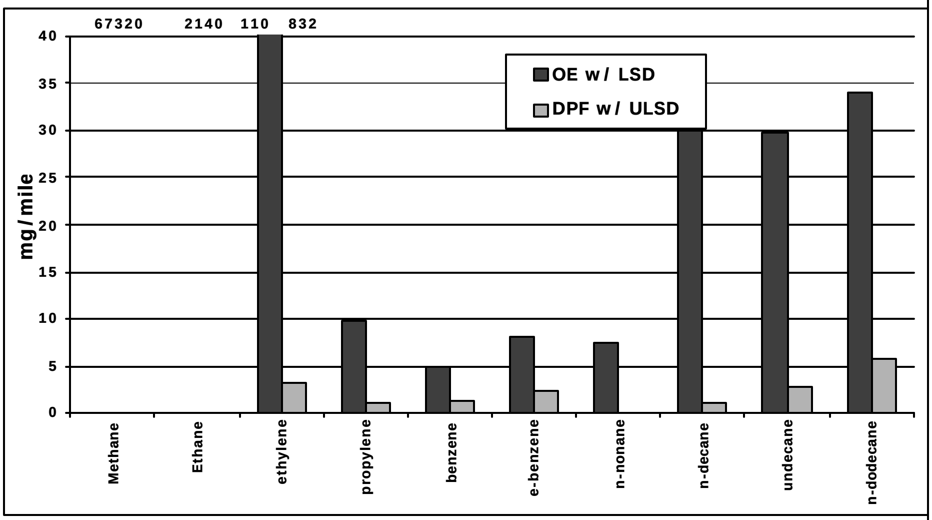


Diesel Particulate Filter

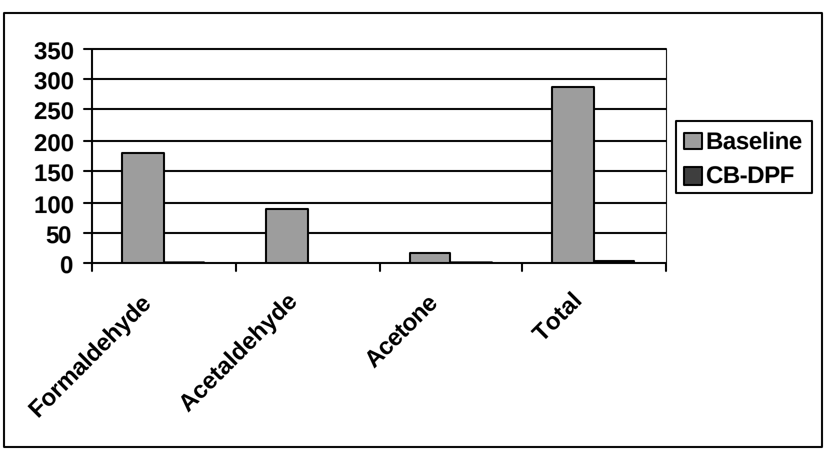
Regulated Emissions S50 - CBD Cycle



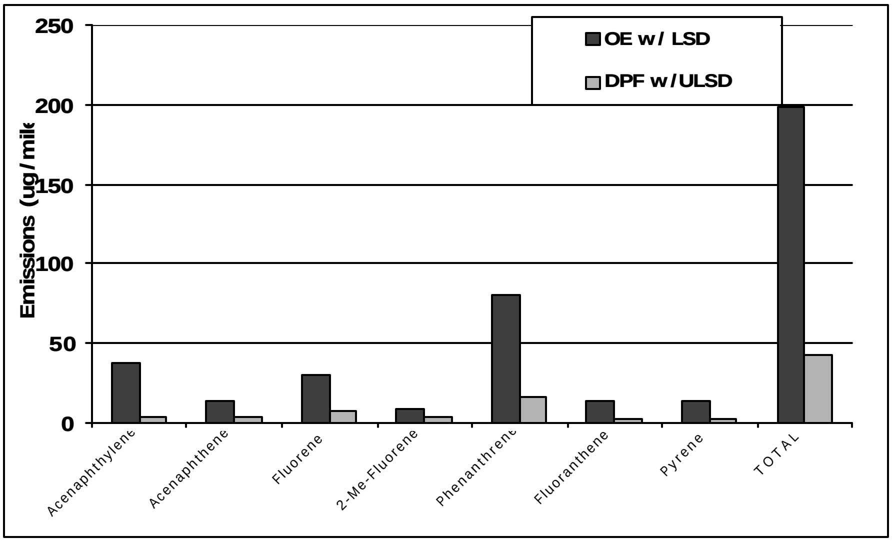
CB-DPF VOC Analysis - NYB Cycle



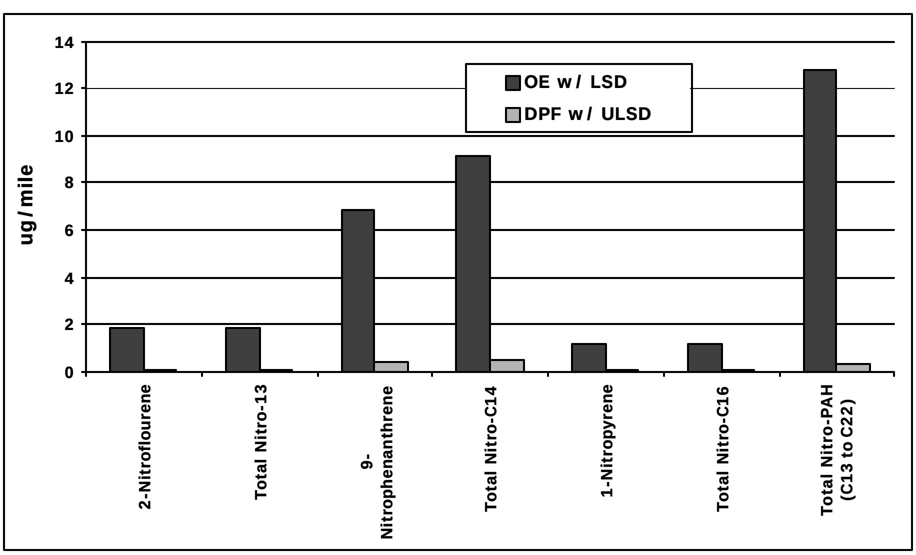
CB-DPF Carbonyl Analysis - NY Bus Cycle



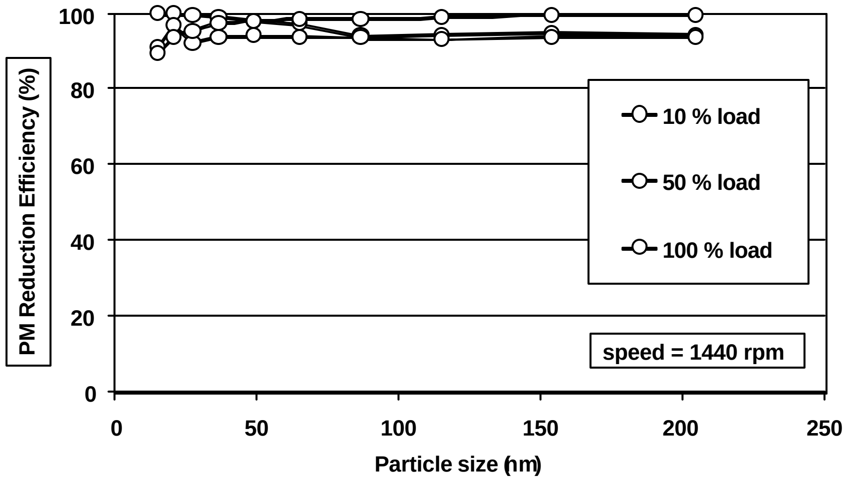
CB-DPF PAH Analysis - NYB Cycle



CB-DPF Nitro-PAH Analysis - NYB Cycle



Filter Particle Size Reduction Efficiency



Selection of a Filter Regeneration Strategy When Retrofitting

- Application and Duty Cycle
- Engine Out Emissions
- Vehicle/Engine Condition
- Fuel Sulfur Level
- Maintenance and Operational Procedures

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Regeneration Strategies Used to Date in Filter Retrofit Applications

- Engine Reliant Regeneration
  - Mining and construction
  - Relies solely on engine exhaust temperature
  - Applicable in limited circumstances
  - No reliance on NO2
- Catalyst-Assist Regeneration
  - Mining, construction, on-road, locomotive, marine, and stationary
  - Promotes the oxidation of collected particulate at lower temperatures
  - Precious metal, fuel-borne, base metal
  - May rely on the formation of NO2

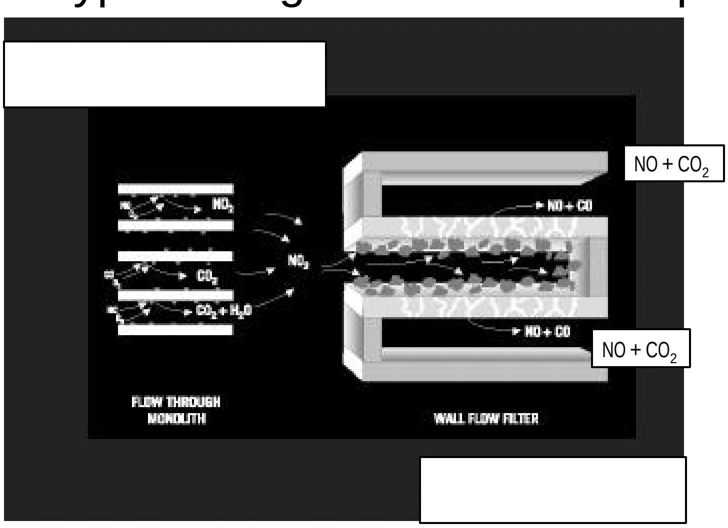
Regeneration Strategies Used to Date In Filter Retrofit Applications (cont.)

- Electric Heater-Assist
  - Mining, construction, and materials handling
  - Shore power (on- or off-board)
  - Performed between shifts
  - No reliance on NO2
- Fuel Burner-Assist
  - Used in stationary engines
  - Inline, full flow fuel burner
  - No reliance on NO2

Regeneration Strategies Used to Date In Filter Retrofit Applications (cont.)

- Intake/Exhaust Throttling
  - Mining and construction
  - Increases exhaust temperature
  - Limited use
  - No reliance on NO2
- Exchange and Off-Board Regeneration
  - Mining and materials handling
  - No reliance on NO2

One Type of Regeneration Technique



Factors Influencing NO2 Emissions

- Catalyst age – fresh catalysts may produce artificially high levels of NO2 initially until they become properly degreened and behave as designed
- Engine-out PM emissions – higher PM emissions will consume more NO2 in the regeneration process
- Catalyst formulation – catalysts can be formulated to convert less NO to NO2 for regeneration purposes
- Catalyst and/or filter size – control technologies can be optimally sized to consume the maximum quantity of NO2 produced during regeneration

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Strategies to Reduce NO2 Emissions from CB-DPF Systems

- Optimization of catalyst formulation and platinum loading
  - catalyst manufacturers can more closely match their catalyst formulations to particular applications to minimize excess production of NO2
  - reduce the NO2 tailpipe emission to 10% to 20% of total NOx emissions as compared to engine-out NO2 emissions of 3% to 10% of total NOx emissions
- Combining a fuel-borne catalysts with a “lightly” catalyzed filter
  - reduce NO2 emissions to less than 10% of total NOx emissions

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Strategies to Reduce NO2 Emissions from CB-DPF Systems

- Thermal management strategies can be incorporated into CB-DPF systems
  - formulate catalysts for lower NO2 production while insuring successful operation should a system experience a worst-case application. Again, the tailpipe NO2 emission levels are expected to be 10% to 20% of total NOx emissions

Summary of NO2 Emissions from Optimized CB-DPF Systems

	%NO2 of Total NOx	
CB-DPF Type	Current	Optimized
Precious Metal	30 to >50%	10 to 20%
Base Metal	n.a.	n.a.
Fuel-Borne	n.a.	n.a.
Fuel-Borne Combined with Lightly Loaded Precious Metal	10%	10%
Precious Metal Combined with Heat Management Strategies	30 to >50%	10 to 20%

n.a.: not applicable

Strategies to Offset NO2 Emissions from CB-DPF Systems

- Reduce overall NOx emissions from engines to minimize or more than offset any expected NO2 emission increase from the use of CB-DPF system
  - Engine-out NOx reduction strategies
    - EGR, engine timing modifications, changes to the engine like specially designed camshafts and coatings
    - Fuel modifications like emulsifiers can be used in combination with CB-DPF systems
- Engine-out NOx reductions of 50% allows for a NO2 emissions equivalent to 20% of total NOx emissions while maintaining, on a mass basis, the baseline engine NO2 emission level

Strategies to Offset NO2 Emissions from CB-DPF Systems

- Reduce NO2 downstream of a CB-DPF system – the use of SCR or a lean-NOx catalyst downstream of a CB-DPF system can be employed to minimize or more than offset any expected increase in tailpipe NO2 emissions
- Repowering with new engines will reduce NOx emissions
  - Sweden's Environmental Zones Program
    - 25% reduction NOx emissions

Other NO2 Slip Investigations with NO2 Assisted CB-DPFs

- Danish Study
  - Euro 0 and Euro 2 buses
  - 5 mode testing
  - NO2 emissions went from 4% to 14 - 18% of total NOx emissions
- SAE Paper 2000-01-1927
  - Different Operating conditions
    - NO2 emissions <15% of total NOx emissions
  - “Stall speed”
    - NO2 emissions ranged from 4 – 41% (avg. 25%) of total NOx emissions (baseline 10%)

Other NO2 Slip Investigations

- Recent BP-ARCO data
  - NO2 emissions averaged of 31.7% of total NOx emisssions
  - Catalyst formulated to produce excess NO2 for demonstration program

Future Strategies Being Investigated to Offset NO2 Emissions from CB-DPF Systems

- HC injection at idle to reduce engine-out NOx emissions at this engine condition
- Systems to decompose NO2 emissions at temperatures in excess of 400 degrees C
- Plasma decomposition of NO2 emissions

Recommendations

- ARB continue to review the NO2 emission issue as new data becomes available
- Model the air quality impacts of the NOx reduction strategies outlined above
- Conduct a real world evaluation of NO2 emissions from CB-DPF systems

Conclusions

- Filters provide great air quality benefits for PM, toxics, CO, and HC emissions
- Not all filter systems rely on the formation of NO2
- Strategies exist to minimize NO2 formation and slip
- NOx reduction strategies exist to offset NO2 emissions
- Other methods of reducing NO2 emissions are being investigated
- NO2 emissions are not an issue for future OE applications